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THE JOURNAL
OF
THE ROYAL ASTRONOMICAL SOCIETY OF CANADA

DEVOTED TO THE ADVANCEMENT OF ASTRONOMY AND ALLIED SCIENCES

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PLATE V.

COMET *b*, 1911 (KIESS).

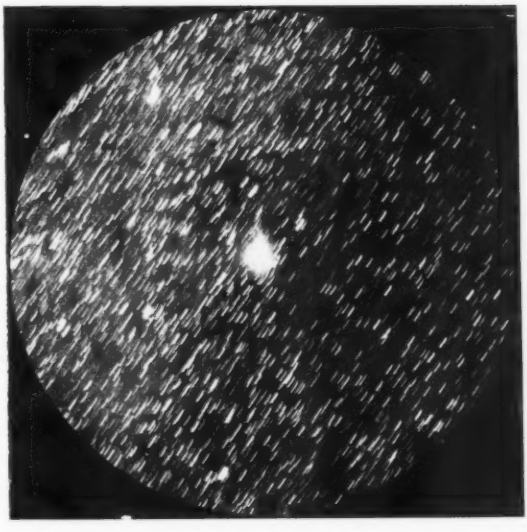
From a negative taken at Lick Observatory, July 8, 1911, by R. S. Sheppard.
Dallmeyer Lens. Exposure 1h. Mid-exposure 3h 53m.0 (P.S.T.)

PLATE VI.

COMET *b*, 1911. (KIESS).

From a negative taken at Lick Observatory, July 24, 1911, by C. C. Kiess. Willard Lens. Exposure 2h. Mid-exposure 2.30 a.m. (P.S.T.)

PLATE VII.



BROOKS' COMET, 1911*c*.

From a negative taken at the Dominion Observatory, Ottawa.
By R. M. Motherwell, August 17, 1911.
Exposure 2h 2m. Mid-exposure 10·21 p.m. (E.S.T.)

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SOME RECENT INTERESTING DEVELOPMENTS IN ASTRONOMY*

BY J. S. PLASKETT

IT has been the custom for the newly elected President of an Astronomical Society to give in his inaugural address a review of the progress of the Science of Astronomy during the year just closed, and I am partly complying with that custom in what I have to say to you to-night. I do not propose, however to attempt to give you a review of the whole field of astronomy. That would be quite impossible in one address. All I shall attempt, therefore, is to select from the material at hand some of the most important results recently attained, and from these again those which are likely to prove of the greatest general interest. In this selection, it is very likely that I shall be guided by my own particular preferences, and I do not, therefore, claim that what I have to lay before you will be entirely representative of the progress of the science.

In my opinion there has been no time in the history of astronomical science when progress has been so rapid and when we

*Address before the Ottawa Centre, February 23, 1911.

seem to be on the eve of so many interesting developments, and I might almost say generalizations, as at the present time.

One of the most significant indications of such development in astronomy is the remarkable co-ordination and correlation that is being so rapidly developed among the different sciences. A few years ago the astronomer made no use of any science but his own, with, of course, its indispensable adjunct mathematics; but now progress in astronomy is impossible without the aid of physics and chemistry, geophysics and geology. We do not know, indeed, how soon we shall be applying biology, with its allied sciences, in the study of such a subject as "Life in Other Worlds," on which we had recently such an eloquent and instructive address by Professor Aitken. Another significant fact pointing towards rapid developments and deductions is the completion or approaching completion of many extensive researches in our science. Astronomy is, perhaps more than any other, a science which requires long continued and systematic investigations to be carried through with faithfulness, unselfishness, and untiring perseverance before any definite results can be attained. All honor to the astronomers of the past, who spent their lives in making observations of which they themselves could not hope to reap any fruit, and all honor to the astronomers of the present, who are unselfishly collecting data which only a future generation can use. The results of past observations are beginning, in many different branches of our science, to be of inestimable service in unravelling some of the mysteries of the universe.

Let us begin our review of the progress of our science at our own globe, and though one would hardly state that the science of geophysics, as the study of the form and constitution of the earth is called, is astronomy, yet it cannot be disputed that only by knowing exactly the dimensions of our earth can we determine the dimensions and distances of the heavenly bodies; and only from a study of the constitution and physical condition of our globe, which must include careful measurements of the spectra of terrestrial elements, can we determine the constitution, the physical conditions, and the radial motions of the heavenly

bodies. We have to proceed to the inaccessible by a study of the accessible, and to investigate the unknown by attacking the knowable, and hence we may safely say that a knowledge of the dimensions and form, the constitution and physical condition, of the earth is a first requisite for a satisfactory study of the heavenly bodies. The science of geodesy, which treats of the figure and size of the earth, is making substantial progress all over the world, and new and more accurate data are constantly being obtained. It is a great satisfaction to me to record that, under the able superintendence of Dr. King, good progress is being made in an accurate Geodetic Survey of Canada. This work, which has only recently been organized, will furnish at the same time results of the greatest practical usefulness, as well as of the highest scientific value. The allied branches of seismology, terrestrial magnetism, and of the determination of gravity are, along with geodesy, gradually changing and crystallizing our notions of the structure of the interior of the earth from the old idea of a thin crust surrounding a molten interior to that of a solid globe whose density and elasticity increase with the depth, at least for some distance, and which acts on the whole as if it possessed the rigidity of steel. Geodetic measurements show that all local irregularities on the surface such as mountains and valleys are completely compensated for at a depth of about 75 miles. This means that if, from the boundaries of equal areas on any part of the earth's surface, lines are drawn towards the centre to a depth of 75 miles from sea level, the amount of matter enclosed is the same in each. This is called the isostatic layer and acts as if it were floating in equilibrium on a liquid at that depth. The comparatively new science of seismology — in which our Observatory is so ably represented by Dr. Klotz, whose method of recording the earth disturbances is, I may say, now being extensively copied — on the other hand shows, from the form and velocity of propagation of earth disturbances, that the interior must be about as rigid as steel. This is further corroborated by measurements, by a kind of seismograph, of the deformation of the solid earth by the luni-solar

attraction, which in the sea produces the tides but which also sets up, though, of course, very much reduced in magnitude, a similar effect upon the land. The more recent advances in seismology have been in the direction of improving the sensitiveness of the instruments and the methods of discussion of data, so that we may hope to gradually obtain definite knowledge of the density, rigidity, and elasticity of the interior, layer by layer.

The increase of data in terrestrial magnetism, on the other hand, seems to have complicated rather than simplified the problem, which is, of course, naturally the case when the fundamental underlying cause or principle is unknown; and this it must be confessed is the case in this science. There can be no doubt, however, of its ultimate solution; and, indeed, we are beginning to see some glimmerings of light in the magnificent work being carried on at the Solar Observatory on Mt. Wilson, where one of the most recent and wonderful results has been to definitely prove that there are magnetic fields in the neighborhood of sun spots. That changes in the terrestrial magnetic elements and solar activity are in some manner connected has long been inferred from the frequent, nearly co-incident appearance of violent magnetic storms following the central transit of prominent sun spots.

We pass naturally then from the earth to the sun, to us the most important heavenly body, as on it is dependent all life on our planet. Very great advances have been made in recent years in the study of the constitution of our luminary, and a great deal of attention is now being paid to researches in this most important branch of astronomy. The International Union for Co-operation in Solar Research, a society or rather group of societies which was organized about five years ago, and which embraces the workers on the sun in all civilized countries, has done much towards unifying and rendering effective the great amount of material collected. A meeting of this Society, which I had the honor and privilege of attending as representing this Observatory and also our Royal Astronomical Society, was held last summer at the Mt. Wilson Observatory, at which many import-

ant questions were discussed and plans for future work outlined. The work of the Union is carried on by several committees which report at the triennial meetings.

Probably the most important action taken was the adoption of a new system of wave-lengths of light. The system in use for the last twenty years was introduced by Rowland, the values being obtained from measurements of spectra made with concave gratings. This system was far in advance of previous ones and was, for a long time, considered practically perfect. More recent investigations have shown, however, that not only were his absolute values in error, every wave-length being too great by about one part in 30,000, which is not a matter of much moment, but that also—a much more serious question—there were relative errors of the order of about one part in 100,000 among the different lines. These errors, due to unknown defects in the gratings, were only discovered when new measurements were made by a different method, that of interference. The new primary standard was first determined by Michelson in 1892 by actually counting the number of waves of the red line in the spectrum of cadmium, in a known fractional part of the standard metre. He found that there were 1,553,163·5 waves in a metre, equivalent to a wave-length ·00064384722 mm. or, as it is usually written, 6438·4722Å. This value has more recently been confirmed by Fabry and Perot and is accepted as the primary standard of the new system. Secondary standards are composed of the wave-lengths of 50 lines, in the arc spectrum of iron between λ4282 and λ6495 which have been independently measured by interference methods by three observers, Fabry and Buisson at Marseilles, Eversheim at Bonn, and Pfund at Baltimore. The accordance of these measures is so good that the range is generally less than one part in a million and the mean of the three is certainly correct considerably within that margin of error. From these secondary standards, tertiary standards are to be obtained by interpolation from grating spectra, and after these tertiary standards have been obtained new measures of the wave-lengths of all lines in solar and terrestrial spectra will be required.

The importance of this work in solar and stellar investigations can not be over estimated, as many important results depend on the accuracy of wave-length values, and incorrect values may lead to erroneous conclusions. This is an instance of what I previously said of the necessary inter-relation of astronomy and physics and the impossibility of successfully attacking modern astronomical problems without the aid of the allied sciences.

One of the important conclusions reached by the Committee on Sun Spots was the practically unchanging character of sun spot spectra. To this may be added the fact, conclusively proved by Professor Hale, that the umbra of sun spots is at a lower temperature than the rest of the sun's surface, and that in sun spots, as first found by Professor Fowler, of London, we have the spectra of some chemical compounds such as titanium oxide, magnesium and calcium hydride, further showing that the temperature is sufficiently reduced to allow the formation of such compounds, which do not appear in the normal solar spectrum. Again we have the discovery of Evershed, of Kodaikanal, India, of radial motions of the vapors around sun spots; and the final discovery by Hale, that many, if not all, sun spots are surrounded by whirls, and that electrically charged particles, which it has been further shown are negatively charged, are carried around by these whirls and produce the magnetic field which is shown to exist around sun spots.

At the high temperature of the sun, magnetism as we know it can not exist, and the field must be produced by such whirls or vortices. The manner in which the magnetic field in sun spots was detected and proved is a splendid example of experimentation to test scientific deductions, and a full justification of the expenditure on the powerful apparatus needed for such work. The whirls surrounding sun spots are shown on photographs of part of the sun's surface, in the light given by the red line of hydrogen. Such photographs are made by the spectroheliograph, an instrument which enable us to photograph the sun's surface in the light of different gases or vapors, and hence records the distribution of these vapors. The great resemblance between

these whirls and the lines of force around a magnet as shown by iron filings, led Professor Hale, the inventor of the spectroheliograph and the discoverer of this effect, to suspect the presence of a magnetic field; and the next question was to verify this suspicion. It was found several years ago by Zeeman that if a luminous vapor is produced between the poles of a magnet, many of the lines of its spectrum are widened. Professor Hale found that the spectrum of a sun spot, with the high dispersion available on Mt. Wilson, showed some of the same lines widened, strengthening his suspicion. Furthermore, when the widened lines produced by a magnetic field in the spectrum of a luminous vapor are examined through a polarizing apparatus many of the lines are split up into doublets, triplets, quadruplets or even sextuplets; and a similar test applied to a sun spot spectrum gave a similar though much weaker effect, conclusively proving the presence of a magnetic field. Comparison showed that its strength was about one quarter of that needed to saturate iron, too weak to produce any magnetic disturbance on the earth, and, therefore, incapable of explaining the frequent coincidence of magnetic storms and large sun spots.

The fact that sun spots are at a lower temperature than the rest of the photosphere has been corroborated by the work of Professor Abbot, who, in his determination of the solar constant, (the amount of heat received from the sun), shows that this is 1 or 2 per cent. less at sun spot maximum than at minimum. The absolute amount of the sun's heat at the surface of the earth is 1·9 calories, which may be more simply stated as the amount of heat per sq. cm. which will raise 1 cubic centimetre of water 1·9° C. or 3·5° F. in temperature in one minute, if the atmospheric absorption is neglected. It has also been proved by Professor Abbot that there are irregular variations in this quantity, and it is hoped that a knowledge of these variations may be of value in helping to predict temperature and meteorological changes on the earth: a problem whose solution, even with all the advances in science, seems as far off as ever.

Another interesting problem, which at the meeting of the

Solar Union, was advanced a stage, is the determination of the Solar Rotation by the displacement of the spectral lines at opposite limbs of the sun. Owing to the rotation of the sun on its axis in about 26 days, one limb approaches and the other limb recedes from us, with a velocity, at the equator, of about 2 kms. per second. If the spectra of the two limbs are brought side by side on the plate, the lines of the former will be displaced to the violet, of the latter to the red; and with a high dispersion spectrograph this displacement will be quite noticeable, of the order of one-tenth of a millimetre. Some work has been done on this problem by Duner at Upsala and by Halm at Edinburgh visually, and more recently by Adams at Mt. Wilson photographically. Besides determining the rate, and the law of decrease of rotation with different latitudes, there are other interesting problems, such as variations of the rate for lines of different substances, which require solution. A combined attack by six institutions, of which the Dominion Observatory is one, on different well-distributed regions of the spectrum has been arranged, and in addition each observer is to measure a common region for comparison of results and removal of systematic error.

Besides these definite advances, much other work in the distribution of the gases and metallic vapors over the photosphere, in comparing the spectra of the limb and centre of the sun, and along many other lines, has been recently accomplished; and we may confidently look for rapid development and increase of our knowledge of the constitution of our luminary in the near future.

Although the study of the sun is most intimately connected with that of the stars, which was recognized at the Solar Union by the appointment of a Committee to discuss the question of the classification of stellar spectra, yet we may, perhaps, turn for a moment to the other members of our solar system and see if any new light has recently been thrown upon the interesting question of conditions on other planets. The perennial question of the objective existence of the fine geometrical markings on Mars, commonly called canals, has been, during the last opposition of

1909, strenuously and ably supported by Lowell and one or two adherents, and equally strenuously and ably combated by many astronomers, chief among whom was Antoniadi. As is well known, the majority of astronomers are unable to see these fine sharp lines, although plenty of other detail is visible. During the last opposition, photography was used to a much larger extent, but I question whether it has settled the matter. Lowell says the principal canals show on his photographs, while others are unable to see them. The only way this question can be settled is, as Aitken suggested, for Lowell to invite some well known observers, such as Barnard, Burnham and others, to Flagstaff at the next opposition and let the whole question be fought out.

Another disputed point is the question of water vapor on Mars. The detection of this water vapor depends upon the visibility of a small band or group of lines in the red end of the spectrum produced by the presence of water vapor. Slipher, Lowell's assistant, photographed the spectrum of Mars and then the spectrum of the moon. The light from Mars, which is, of course, reflected sunlight, passes twice through Mars' atmosphere and then through the earth's atmosphere. The light from the moon, which has no atmosphere, passes through the earth's atmosphere only. If now there is water vapor in appreciable amount in the atmosphere of Mars this band should be stronger in the spectrum of Mars than in that of the moon. Slipher found that it was stronger in the Martian spectrum, but unfortunately some little time elapsed between the two exposures, and there is a possibility that the greater strength of the band was due to change in the amount of water vapor in the earth's atmosphere. Director Campbell, of the Lick Observatory, considered the question of sufficient importance to organize an expedition, carrying instruments to the summit of Mt. Whitney, elevation 14500 ft., at which altitude only one-fifth of the earth's water vapor is above and four-fifths below. Any small difference between the moon and Mars bands will show relatively more conspicuously than at the elevation of Flagstaff, which is about 7000 ft. His photo-

graphs were made within a few moments of one another, and with Mars and the moon at the same altitudes, and are hence directly comparable. I saw them myself last summer at Mt. Wilson, and I can say that there is no discernible difference in the vapor bands in the two spectra. The bands are very weak and evidently due to the small amount of water vapor present in the earth's atmosphere above Mt. Whitney. Campbell comes to the conclusion that there is no spectroscopic evidence of the existence of water vapor on the planet. Although he specifically states that he does not contend that Mars has no water vapor he says that it is too slight to be detected by the spectroscopic method and is probably considerably less in quantity than that present in the earth's atmosphere above the summit of Mt. Whitney.

The question of the suitability of Venus for organic life seems to depend upon the determination of its rotation period. If, as is now mostly believed, it always turns the same face to the sun then the one side will be baked and the other frozen. If, on the other hand, it turns on its axis in about 24 hours, then it is practically certain to be in a condition to support life. The only possible test between the two theories is the spectroscopic one, as in the solar rotation, by observing the line shift at opposite limbs. In this case, however, we have difficulties owing to the bad seeing at the comparatively low altitude of Venus and the disturbance of the image, so that it is difficult to determine in what region of the planet the spectra were made.

The advent of Halley's Comet proved possibly as disappointing to astronomers as to the general public, for it did not show many unusual features and not much additional knowledge concerning the nature of comets was obtained. The motion of a detached part of the tail, as determined from three photographs at Williams Bay, Honolulu and Beirut, showed the presence of an accelerating force, as its velocity relative to the head increased from 23 miles to 37 miles a second in 7 or 8 hours. To my mind the most remarkable feature of its return was the accuracy of the computation so successfully carried through by Messrs Cowell and Crommelin, in which they predicted its perihelion passage

within less than three days. When considered in connection with the large number of disturbing elements to be taken into account and the exceedingly complex and cumbersome calculations required, their ephemeris was a marvellous piece of work, and they well deserved the recognition it received.

Before discussing some of the advances in our knowledge of the sidereal universe it has seemed desirable to refer to the improvements effected in apparatus for observation. At the head comes naturally the large reflecting telescope with a mirror of 60 inches diameter, recently installed on the summit of Mt. Wilson, California, at an elevation of 5886 ft. This telescope was designed and the mirror was figured by Prof. G. W. Ritchey, Supt. of Instrument Construction of the Solar Observatory, who also is doing much of the photographic work with the telescope. I had the privilege of carefully examining the mechanism and of observing with the telescope, and it is certainly a superb instrument. The optical properties are practically perfect; and the difficulty of temperature changes, the most troublesome met with in reflectors, has been successfully overcome. The mechanical construction is also unexcelled, and the instrument, although its moving parts weigh 23 tons, drives with the greatest smoothness and ease. The most magnificent photographs of star clusters and nebulæ ever made have already been obtained with the instrument, and its light-efficiency in spectrographic work is wonderful. It can obtain in five minutes a spectrum of a 5th magnitude star that requires with our refractor over an hour. It is no wonder that such an instrument excited the envy of all astronomers who saw it, and Professor Ritchey was pardonably proud of his masterpiece.

We turn from this to, comparatively speaking, a rather insignificant instrument, for measuring the brightness of the stars. The subject of stellar photometry has always been a difficult one, as all the photometers hitherto devised have depended upon eye estimates or comparisons of the relative brightness of the star with either another star or an artificial light, made by ingenious devices to resemble and be brought close beside

the star to be measured. There is, in all such methods, the possibility of psychological errors and it has not been possible to obtain, except in special cases, results with a lower probable error than about one-tenth of a magnitude. In the case of the comparison of two stars brought into the one field and equalized in intensity by polarizing apparatus, the probable error is, perhaps, as low as three or four hundredths of a magnitude. In another method also, in which out-of-focus images of the stars are photographed, the density of the resulting discs have then to be measured by a photometer and we have errors of the same order. The new method, however, does not depend on eye estimates but on the change in electrical resistance of the element selenium when exposed to light. If a selenium cell is placed on the end of a telescope and an image of the star to be measured thrown on it, the change of resistance can be measured by a Wheatstone bridge arrangement and very accurate values of the brightness obtained. Professor Stebbins, who has been working with much ability and energy on this problem for the last three years, deserves much credit for his success in a difficult research. He has recently made new measures of the light curve of the well known variable star Algol, and the probable error of a determination at maximum is $\pm$ ·006 mag., at minimum $\pm$ ·023 mag. The accuracy of his observations enabled him to detect a secondary minimum which had never before been seen and which indicates that the companion whose eclipse of the bright star causes the variability is not dark but light. Taking the most probable value of the parallax or distance of the star, he finds that the bright star, which has about the same diameter as the sun, gives 240 times as much light, while the faint hemisphere of the companion gives 16 and the bright hemisphere 28 times the light of the sun.

Such results as these are most interesting, and it is only by combination of several different methods, in this case of the light variation by a photometer, the orbital elements by the spectroscope, and the distance by parallax measurements, that we can obtain them, and that we can hope to increase our knowledge of

stellar systems. Another interesting variable is μ Herculis, whose orbital elements were determined by Schlesinger at Allegheny from radial velocity measurements with the spectroscope. He finds that the brighter star is about 5,000,000 miles in diam.—6 times our sun—is 7·5 times as massive but only $\frac{1}{27}$ as dense as the sun. The fainter star is 2·9 times as massive but only $\frac{1}{70}$ as dense. The parallax of this star is not known, but if it is as luminous as Algol, the brighter star must give out about 8000 times as much light as the sun.

There has been a very marked advance in recent years in stellar spectroscopy, particularly in the line of the determination of the radial velocities of the brighter stars, and several observatories are now engaged in this work. Accurate radial velocity measures were first obtained by Professor Campbell at the Lick Observatory in 1896 or 1897, and for many years he was practically the only one doing that work. Campbell's work has been the determination of the radial velocity of all stars in the sky, containing spectra with well measurable lines, which are brighter than the 5th visual magnitude. This work is now practically completed, and a preliminary value of the direction and magnitude of the sun's motion in space, with numerous other interesting and valuable deductions, are just being published.

In his work and that of Frost, of the Yerkes Observatory, who is measuring the radial velocities of Orion type stars, many spectroscopic binaries—stars whose radial motion varies, and which are hence accompanied by invisible companions, as distinguished from visual binaries where both stars are seen—have been discovered, and it is believed that not fewer than one in three of all stars must have a companion of approximately the same size, thus eliminating in these cases all possibility of a planetary system like our own. Great advances have been made in determining the orbits, the character of the motion around one another, of these binaries, and the two institutions most active in this line of work are the Allegheny and the Dominion Observatories. Of the seventy spectroscopic binary orbits determined our Observatory has obtained 16; which, considering that the

aperature of its telescope is only half or less that of others engaged in the work and that it has been established only a comparatively short time, is a creditable showing. The great strides made in the determination of Spectroscopic Binary Orbits has led to no less than three summaries of the results, containing deductions of important conclusions from them: by Campbell, Schlesinger and Ludendorff. I have not time to enter into the results deduced from these discussions except to say that it was shown that most binary systems probably originate from a revolving parent nebula which, while condensing, separates into two masses, and that these masses, as condensation proceeds, and by the influence of tidal action, gradually increase their distance from one another; this being accompanied, of course, by an increase in the period and also, as the results show, by an increase in the eccentricity—a greater departure from the circular form—of their orbits. There is no sharp line of distinction between spectroscopic and visual binary orbits except that the latter have much longer periods and generally higher eccentricities.

The information already obtained, and that which will in the near future be obtained about these spectroscopic binary systems, has a most important bearing on the problem of the constitution of the sidereal universe; and we must now come to consider recent progress in our knowledge of the extent and form and motions of its parts. This is certainly the most important problem in astronomy, as practically all observing data whether astrometrical or astrophysical, whether dealing with the absolute positions, proper motions, and radial velocities of the stars, with their distances, dimensions, and densities, with their evolution and spectral type, or with the investigation of variables and binary systems, are all either directly or indirectly obtained with this end in view and all are, undoubtedly, directly of use in its solution. As I said in the early part of the paper, there has been no time when so many different investigations were converging towards this end, and I will try and give you some details of the principal results.

One of the most striking of recent advances has been the

discovery of star drifts and star streams in the sidereal universe. These have been discovered by statistical methods applied in the discussion of the absolute positions and proper motions of stars and also by the aid of their radial velocities. The one man to whom we owe more than any other the development of this work is Professor Kapteyn, who is Director of what is called the Astronomical Laboratory of Groningen, where the instruments of research are not telescopes and spectroscopes but measuring machines and mathematical tables, where no observations are taken but photographs are measured and observations discussed. I will try and give you a general idea of the present state of our knowledge in regard to the motions of the stars. Although we call them the fixed stars the term is a misnomer, for they are all in motion. We can measure this motion in two components. First the motion at right angles to the line of sight, across the sky, determined from successive observations of the star's position in the sky and measured by the change of position in seconds of arc in a year or a century. The change of position varies between about 9″ per year and zero; the average annual proper motion, as it is called, for first magnitude stars being ¼″ and for sixth magnitude about $\frac{1}{25}$″, or 4″ per century. Second, the motion in the line of sight, or radial velocity, measured by the spectroscope, which again varies between 0 and about 250 km. per second, the velocity of a faint star in the southern hemisphere determined last year. It is evident that in order to get the true direction and velocity of a star we must know, in addition to its radial motion, its velocity in kms. per second at right angles to the line of sight. If its proper motion is known this can be readily computed when we know its distance, and hence we can obtain the direction and magnitude of its motion.

In determining these motions we have to remember that we are on a moving body, the earth, which has a velocity of revolution around the sun of about 20 miles per second, and we must also remember that the sun, which is one of the stars, is also in motion. That this is the case has long been recognized, and the direction of this motion was determined from the proper motions

of the stars by Sir William Herschel over 100 years ago. The method of doing this can be readily understood, for if we imagine the stars to be moving in all directions at random, it is, nevertheless, evident that in the portion of the sky which we are approaching, the general tendency will be for them to open out, while they will tend to close in in the opposite direction, and to drift backwards at the sides. Hence, if the motion of the stars is at random, it is only a question of mathematics to determine the direction and magnitude of the sun's motion in space.

Over twenty different determinations, based upon the proper motions of different numbers of stars, have been worked out, which all agree reasonably well in showing the sun to be moving towards the dividing line between Lyra and Hercules just a little south and east of the bright star Vega. This point has shifted around considerably between Hercules and Lyra, but the last determination, from Boss' Preliminary General Catalogue, issued only last year, places it where I have just stated (R. A. 270°·5, Dec. + 34°·3).

If we consider, on the other hand, a determination of the apex of the Sun's Way, as this point is called, derived from the radial velocities of stars, we find it to be in a somewhat different position. We have had three or four determinations of the solar apex from radial velocity measures; but none of these need be considered here except that obtained last year by Professor Campbell, Director of the Lick Observatory, the pioneer and foremost exponent of accurate radial velocity determinations, whose methods have been universally followed and their accuracy never excelled. I place the results of his fourteen years' work as the most important astronomical result announced during the year. In determining the velocity and direction of the sun's motion, the radial velocities of 1073 stars brighter than the 5th magnitude, well distributed over the sky, were used, 1020 of which were determined by spectrographs at Lick and Santiago, 40 were obtained from other observations and 13 were of nebulæ visually observed by Keeler. The position of the apex, or point towards which the sun is moving, is somewhere,

about 7° south of that obtained from the proper motions of the stars (R. A. 272°·0 ± 2°·5, Dec. 27°·5 ± 3°·0), nearly 10° due south of Vega.

Of the two determinations the one obtained from a discussion of the proper motions is of the greater weight, for two reasons — first, the method is more suitable for determining direction; second, the number of stars employed is considerably greater.

On the other hand the discussion of radial velocities gives us a much more reliable value of the velocity of the solar system than proper motions. The velocity from Campbell's discussion comes out as 17·77 km., (11 miles per second), and this is undoubtedly very near the truth.

Many other interesting conclusions were reached by Campbell, but time will not permit me to dwell on them, and we must consider further the question of motion of the stars.

It is evident that if a comparison of the motions of the stars shows the sun to be moving towards Vega, then the apparent motions of the stars themselves must, on the whole, be to a point on the celestial sphere directly opposite. Such a motion of the stars, made up not of motions all in the one direction but of motions in all directions with a preponderance in one direction, is called a drift of the stars; and there is thus a drift of the stars due to the solar motion towards or having as apex a point in the Southern Hemisphere nearly opposite Vega, with a velocity of about 11 miles per second.

About five years ago Kapteyn, from a careful examination and discussion of the proper motions of the Bradley stars, came to the conclusion that there is not one drift of stars, that due to the solar motion, but two drifts, moving in different directions. This conclusion has been confirmed by Eddington, Dyson, Hough and Halm, and the latest values by Eddington from the proper motions of Boss' Catalogue place the apexes of these two drifts as follows:— Drift I. towards the constellation Lepus between Canis Major and Orion, about 10° west of Sirius (R. A. 90°·8, Dec. − 14°·6). Drift II. towards the southern constellation

Pavo or away from the northern constellation Camelopardalis (R. A. 287°·8, Dec. − 64°·1). He finds that Drift I. is moving apparently nearly twice as fast as Drift II. and contains about 60 per cent. of the stars.

When, however, allowance is made for the solar motion we find that these two drifts are moving, one towards the constellation Orion about 8° northeast of α Orionis (Betelgeux), R. A. 94°·2, Dec. + 11°·9, and the other in the opposite direction: exactly as if we were in the midst of two sidereal systems interpenetrating one another—a very fascinating hypothesis.

This hypothesis of the two drifts deduced from a discussion of the proper motions of the stars is strongly confirmed by Campbell's investigation of the radial velocities. We should expect, if there are two drifts of stars towards and from this point in Orion, that the radial velocities of stars in this and the opposite point of the sky should be greater than at points at right angles to these directions. Campbell found that the velocities in the vertex and anti-vertex are 33 per cent. greater than at points about 90° from these.

Besides the two drifts of stars we have smaller groups of stars in different regions of the sky, all the stars in a group having a motion approximately in the same direction and of the same velocity. Such groups are quite different from drifts where there is only a preponderance of motion in one direction, and are called star streams. Perhaps an analogy may help to make the matter of star drifts, star streams, and solar motion clearer. If you imagine yourself walking in a park where there are many people moving about at random it is evident that, speaking generally, the space between those you are approaching opens out, between those you are moving away from closes in, while people at either side, on the whole, appear to move backward. The apparent motion of the mass due to your own motion is analogous to the star drift due to the solar motion. If among the people there are, say, a company of soldiers or a picnic party moving in a given direction we have an analogue of a star stream.

It was first pointed out by R. A. Proctor, about 40 years

ago, that five of the stars of the Dipper have proper motions in the same direction and of approximately the same magnitude; and this stream has within the last two years been thoroughly investigated by Ludendorff, of Potsdam, who determined their radial velocities, and more recently by Herzsprung, who found that the stars Sirius and α Coronæ Borealis as well as some fainter stars also belong to the group. It is a comparatively simple problem mathematically to determine the mean parallax or distance of such a stream when we know the convergent point or apex and the proper motions of the group with the radial velocities of two or three of them. The parallax of the five stars of the Dipper comes out as $\cdot 0352''$, which is equivalent to a light journey of about 90 years, while they are all moving at a velocity of 20 km. per sec. towards a point in the southern part of the constellation Sagittarius ($\alpha = 303°{\cdot}2$, $\delta = -36°{\cdot}6$). It is shown further that the stars of this group are at the same order of distance apart as the sun is from some of the nearest stars—about 20 or 30 light years—and that they are about 100 times as bright as the sun.

Another group or star stream has recently been found in the constellation Taurus by Professor Boss, consisting of 39 stars forming a roughly globular cluster about 15° in diameter. These stars are all moving with a velocity of about 40 km. (25 miles) per second towards a point in the northeastern part of Orion, about 35° from the centre of the group. Their parallax, computed as before, is $0''{\cdot}025$, or 130 light years distant. Boss has calculated that in 65,000,000 years they will form a globular cluster about 21′ in diameter and of magnitudes 9 to 12.

The most recent discoveries in star streams were given by Professor Kapteyn, at the Solar Union meeting, on Mt. Wilson, last August. He has found, by selecting from Boss' Catalogue all the stars of the Orion type, characterized by the appearance of helium lines in their spectrum and so called since most of the stars in the constellation of Orion are of this class, that in a large region of the sky they are moving in nearly the same direction and at nearly the same rate. This region contains the con-

stellations Scorpio and Centaurus, covering 4500 square degrees and extending roughly from 12^h to 18^h R. A. to and from Dec. 0° to − 60°. In another region of 1300 square degrees in Perseus from $2^h\ 50^m$ to $4^h\ 30^m$ R. A. and from + 15° to + 55° in Dec., all the stars of the same type are moving in a different direction. When motion of the sun among the stars is allowed for, Professor Kapteyn finds that these apparent motions are equivalent to streams moving in exactly opposite directions and at equal rates. He finds these stars are very distant from the sun, from about 125 to 500 light years.

It is evident that the sidereal universe is a complex structure and having complex drifts and motions of stars and systems of stars in its parts. We may be able to get a further idea of the magnitude of the problem by considering some of the recent results obtained for stellar distances. We all know, of course, that the nearest fixed star, α Centauri, is slightly over 4 light years distant, about 275,000 times the distance of the earth from the sun, 25 millions of millions of miles. There has been a very marked advance in recent years in the determination of the distances of the stars, so that we now know with reasonable accuracy by direct methods the parallax or distance of about 200 stars. There are several indirect methods, one of which has been mentioned in connection with star streams, which give us what may be called mean or average parallaxes of groups of stars. I have not time to go into these methods, but it may suffice to give a couple of tables indicating in a general way the average distances of stars of different magnitudes and of different types. If we take the blue stars, those of the 2nd magnitude are on the average 100, of the 4th 200, of the 6th 400, of the 8th 800, of the 10th 1600, and so on, light years away; doubling for a change of 2 magnitudes: while if we consider stars of different types we have from a recent paper of Kapteyn's that the average distance of 5th magnitude stars is for the helium stars 500 light years, for the hydrogen 300, for the solar 130, for the late solar or fluted spectra 270 and for the carbon or deep red stars 4500 light years.

Recent spectroscopic studies of some of the nebulæ have

indicated, from the fact that their spectra are somewhat similar to our sun, that they are, probably, composed principally of solar type stars. If we consider the Great Nebula in Andromeda, which is a typical example, we are forced to the conclusion, if such is the case, that it must be tens of thousands of light years distant and probably forms a universe by itself. Indeed, it is practically certain that the globular clusters, like that in Hercules, which some of you have seen through the telescope, are compact aggregations of stars whose average distances from one another are of the same order as the distances of our sun from the nearer stars, say 5 to 20 light years and, in that case, the clusters are of the order of 10000 light years distant from us.

It is quite certain then that the visible Sidereal Universe is of almost inconceivable dimensions and of a structure so complex that, although we are gradually obtaining a knowledge of some of the motions and some idea of its form and arrangements in part, we are yet far from any clear notion of its constitution. Yet when we consider how the human mind, though inhabiting for only a few years this minute planet, accompanying a comparatively insignificant star of the system, has been able to reach out to the inconceivable depths of space and reduce some of the confusion of stars to orderly systems, has been able to deduce the laws which govern these systems, thus unifying, in a certain degree, all the wonderful phenomena of suns and planets, comets, stars, nebulæ and clusters, into one whole, we do not lose hope that eventually it will be able to much further unravel the mystery of the universe.

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THE ORBIT OF *b* PERSEI

By J. B. Canson

THE star *b* Persei ($\alpha = 4^h\ 10^m{\cdot}7$, $\delta = +50^\circ\ 03'$, mag. 4·5) was announced a binary by Professor Campbell early in 1910* from measures of four plates taken, two in 1903, one in 1906 and one in 1909. Its spectrum is of *A* type and a few of the plates obtained here show double lines. In the second spectrum thus appearing, the lines are not at all well defined and measures on them are only fair as will be seen by the magnitude of the residuals. The lines which show doubling are H_γ, and $H\delta$ and in one case the iron line λ4045.

There were taken in all thirty-six plates dating from October 10, 1910 to April 24, 1911. The lines are about the average for this type. Being a double spectrum and the two components being separable in only a few plates, the measuring is more difficult than it would otherwise be. All plates were taken with the single prism spectrograph, the length of time required for using the three prism being too great for a star of this magnitude. Seed 27 plates were used throughout for the same reason although a finer grained plate might have been very advantageous for showing doubling of lines.

The lines measured were :—

Element	Wave-Length
Hydrogen	4861·527
"	4340·034
"	4101·800
"	3970·177†
Magnesium	4481·400
Iron	4549·766
"	4045·975
Calcium	3933·825

* *A. N.*, No. 4374.

† Only in one or two plates.

Other iron lines appeared in a few of the plates but for the most part were not measurable.

A table of observations follows. The phases are from corrected periastron, the residuals from the corrected curve. A table of the Lick observations is attached showing the residuals they give from the curve accepted.

Plate	Julian Day	Phase Corrected from T	Velocity (Primary)	O – C Residual	Velocity Secondary	Res.
3728	2418955·830	1·191	+ 35·4	7·6		
3738	957·760	·007	– 27·6	1·6		
3809	985·63	·445	+ 12·8	9·2		
3819	9011·72	·561	+ 41·8	+ 5·3		
3826	012·79	·114	– 36·6	– 9·5		
3854	016·72	·989	+ 51·3	– 5·2		
3862	018·73	1·472	– 8·9	+ 4·1		
3870	021·62	1·297	+ 9·2	– 16·8		
3875	022·64	·800	+ 50·7	– 3·3		
3885	027·54	1·118	+ 51·9	+ 1·4	81·5	– 5·0
3907	036·715	1·129	+ 59·7	+ 9·7	70·4	+ 1·6
3919	042·719	1·024	+ 51·0	5·5		
3931	049·680	·340	+ 4·4	– 2·6		
3939	053·724	1·338	+ 24·2	+ 6·7		
3949	054·792	·878	+ 59·3	+ 2·8		
3960	055·666	·225	– 10·0	+ 3·0		
3963	056·642	1·201	+ 48·4	+ 6·4		
3990	083·610	·678	+ 43·3	– 3·7	78·7	– 10·7
4005	088·530	1·016	+ 59·0	+ 2·5		
4017	093·510	1·414	– 3·3	– 2·8		
4018	095·490	·340	+ 5·8	– 0·0		
4031	096·530	1·379	+ 14·1	+ 2·0		
4033	097·643	·965	+ 60·2	+ 3·6		
4034	098·491	·286	+ 3·1	+ 6·6		
4057	102·549	1·289	+ 20·8	– 6·7		
4068	103·580	·793	+ 45·3	+ 3·7	– 119·0	– 33·0
4078	104·583	·269	– 14·3	– 8·3		
4087	106·542	·700	+ 55·6	+ 6·6		
4100	109·560	·664	+ 45·4	– 0·6		
4112	110·550	·127	– 22·7	+ 2·5	+ 168·8	– 28·2
4135	120·542	·955	+ 58·7	+ 2·0	– 77·3	+ 22·7
4143	124·658	·489	+ 33·5	+ 5·5		
4176	137·542	1·154	+ 47·8	– 0·2		
4185	2419138·536	.621	+ 34·4	– 7·6		
4195	141·550	·580	+ 42·1	– 4·9		
4246	151·542	1·403	+ 3·5	+ 2·5		

Lick Observations

Julian Day	Phase	Velocity	Residual
2410422·024	1·2002	+ 28·3	– 12·5
435·980	1·4283	3·5	– 0·5
7473·978	0·8397	+ 40·5	0·3
8552·017	·5908	+ 52·5	+ 12·5
960·909	·1610	– 31·4	– 9·6

The observations were combined into fourteen groups and these normal places used in obtaining, by means of Dr. King's graphic method, preliminary elements for the orbit. The normal places with mean velocities, mean phases, weights and residuals from final curve are given below.

NORMAL PLACES

	Julian Day	Phase	Velocity	Weight	Residuals
1	2419045·213	·404	+ 21·7	1	2·21
2	100·036	·500	+ 39·6	2	+ 1·04
3	099·214	·682	+ 48·3	2	1·66
4	068·464	·810	+ 49·4	1·5	4·64
5	073·649	·961	+ 56·7	2	0·10
6	060·281	1·020	+ 55·4	1	− 0·37
7	078·533	1·137	+ 52·5	2	+ 3·41
8	018·838	1·197	+ 43·5	1	+ 0·77
9	064·280	1·312	+ 19·8	2	− 3·93
10	116·991	1·399	+ 6·0	1·5	+ 1·88
11	018·730	1·472	− 8·9	·5	+ 3·52
12	017·472	·103	− 27·3	1·5	− 0·83
13	085·016	·252	− 12·6	·5	− 3·81
14	082·780	·318	+ 4·1	1·5	+ 2·11

The preliminary elements obtained were :—

$$P = 1{\cdot}52732 \text{ days}$$
$$e = {\cdot}25$$
$$\omega = 150^{\circ}$$
$$K = 43{\cdot}5 \text{ km.}$$
$$\gamma = 21{\cdot}92 \text{ km.}$$
$$T = 2418956{\cdot}145 \text{ J. D.}$$

A least squares solution was carried through with the result that the following corrections were made to the elements,—

$$\delta\gamma = + 1{\cdot}20 \text{ km.}$$
$$\delta K = - 1{\cdot}925 \text{ km.}$$
$$\delta e = - {\cdot}038$$
$$\delta\omega = + 0^{\circ}{\cdot}85$$
$$\delta T = + 0{\cdot}^{d}018.$$

The value of Σpvv was greatly reduced, being brought down

from 241 to 128. Disagreement between computed and observation equation residuals led to a second solution being made and further corrections found,—

$$\begin{aligned}
\delta\gamma &= - \cdot 03 \text{ km.} \\
\delta K &= + \cdot 31 \text{ km.} \\
\delta e &= + \cdot 008 \\
\delta\omega &= + 0^{\circ}\cdot 90 \\
\delta T &= + \cdot 0035 \text{ days.}
\end{aligned}$$

The new values for the elements gave satisfactory comparison between computed and observation residuals and a second lowering of Σpvv from 128 to 126.

The probable error of a normal place of weight unity was computed and found to be $\pm$ 2·5 while that of a plate of average weight was $\pm$ 3·9.

The probable errors of the elements were also computed and are given below after the final values of each.

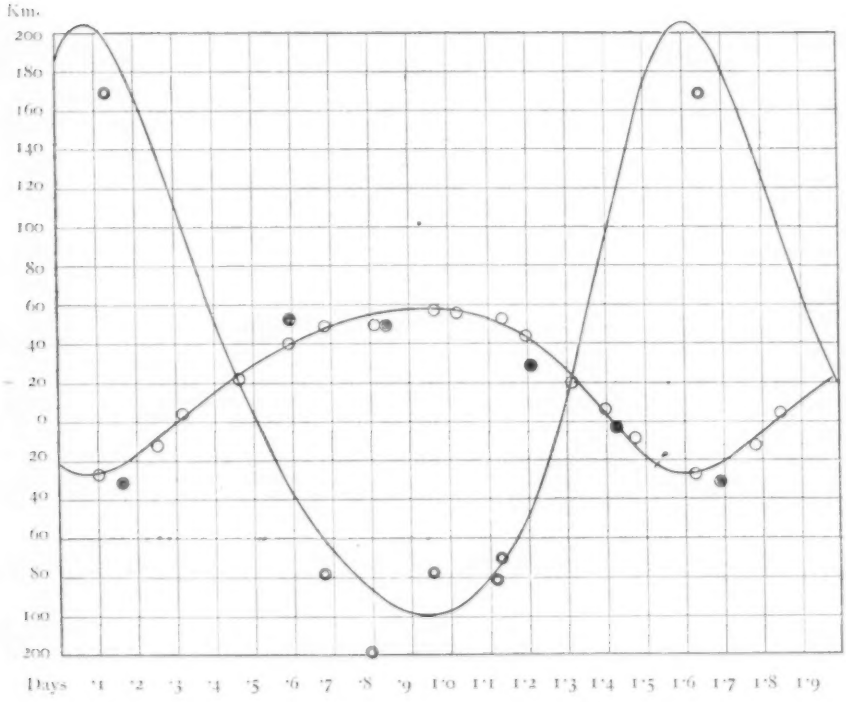
The following table gives a summary of the values of the elements preliminary, first corrected and final :—

Elements	Preliminary	First Corrected	Final Values	
P	1·52732 days	1·52732 days	1·52732 days	
e	·25	·212	·22	$\pm$ ·021
ω	150°	150°·85	151°·75	$\pm$ 2°·08
K	43·5 km.	41·575 km.	41·89 km.	$\pm$ 0·97
$\frac{1}{2}\gamma$	21·92 km.	23·12 km.	23.09 km.	$\pm$ 0·57
T	2418950·145	2418956·163	2418956·166	$\pm$ 0·02
$a \sin i$			837,000 km.	

Coming to the secondary, only six plates showed lines measurable. No attempt was made to get elements independently of the primary, the number of plates not being considered sufficient for that. The value of γ and T finally accepted for the primary were taken for the secondary, ω_1 taken $180^{\circ} + \omega$, and the K was obtained by trial graphically. Those given probably suit the six observations as well as any. The elements are :—

$$P_1 = 1{\cdot}52732 \text{ days}$$
$$e_1 = {\cdot}22$$
$$\omega_1 = 331°{\cdot}75$$
$$K_1 = 152{\cdot}5 \text{ km.}$$
$$\gamma_1 = 23{\cdot}09 \text{ km.}$$
$$T_1 = 2418956{\cdot}166 \text{ J. D.}$$
$$a_1 \sin i_1 = 3{,}048{,}000 \text{ km.}$$

The relation existing between the masses of the two bodies is given by $M : M_1 = K_1 : K = 152{\cdot}5 : 42$ or $3{\cdot}6 : 1$.



Velocity Curve of *b* Persei

The figure gives the two curves. The double circles are the observations on secondary component and the double circles with central dot are Lick observations.

I beg in conclusion to acknowledge the interest in and encouragement given by Dr. King throughout this work.

DOMINION OBSERVATORY,
OTTAWA, CANADA,
June, 1911.

PERSONAL ERRORS OF BISECTION IN MERIDIAN CIRCLE WORK

By D. B. Nugent

IN determining the time of transit of a star over the same meridian, it has been found that the times obtained by two observers differ by a small but constant quantity. One observer, perhaps, acquires the habit of setting his wires always to the left of the star-image regardless of the direction of apparent motion of the star, while the other sets always to the right. In the former case the observer would observe the transits of stars north of the zenith at upper culmination too late and those south of the zenith too soon, and in the case of the latter it would be the reverse. This error of setting always to the left, or to the right, of the true setting is the personal error of bisection.

The object of this paper is to determine the magnitude of these errors in the case of the two observers — R. M. Stewart and D. B. Nugent — who are engaged in transit observations with the Meridian Circle at the Dominion Observatory. In order to do this certain stars, varying from 10° to 80° in declination, were selected from our observing list and grouped in pairs according to their right ascension and their declination. In most cases the stars of a pair did not differ by more than 10^m in right ascension, and in no case did the difference exceed 30^m, while the difference in declination was always less than 5°. By using a reversing eye-piece, which consists of a glass prism mounted in front of an ordinary eye-piece, the position of the star-image can be turned through 180° by rotating the prism through 90°, and thus the apparent motion of a star across the field of the telescope reversed. If the star, the eye-piece being normal, crossed the meridian from west to east, then on turning the prism through 90° it would appear to cross from east to west. Each night the pairs were observed, one star was taken reversed, the same star

being reversed on alternate nights. By comparing the observations on two successive nights the difference between a reversed and a normal observation was obtained.

The apparent right ascension of each star was determined for every night it was observed by using the following equation

$$\alpha = \Delta T + T + c \sec \delta + m + n \tan \delta,$$

where α = the apparent right ascension,
ΔT = the clock correction,
T = the clock time of transit of star;
$c \sec \delta$, m and $n \tan \delta$ are corrrections depending on the collimation, level and azimuth of the instrument.

The clock correction ΔT used was that given by 3 or 4 stars whose declinations were not more than 10 degrees greater or less than the pairs to be compared and whose right ascensions were not greater nor less by more than an hour. The m and n were determined from all the stars observed on that night. The difference $\Delta\alpha$ between the value of α thus obtained and α_0 that given by the catalogues is a measure of the error. The value of $\Delta\alpha$ was found for a reversed and a normal observation and the difference $(r - n)$ was twice the error of bisection. For the sake of comparison these values were all expressed in equatorial interval.

An example of the computation follows :—

Stars	Date	ΔT	ΔT	Obs.	T	α	α_0	$\Delta\alpha$
		s	s		s	s	s	s
823		14·07						
831		14·09	14·10					
852	Sept. 28	14·13						
833 }	1910			r	2·52	16·49	16·54	− ·05
835 }				n	47·61	61·58	61·58	·00
823		14.12						
831		14·06	14·08					
852	Sept. 30	14·07						
833 }				n	2·57	16·54	16·52	·02
835 }				r	47·62	61·59	61·55	·04
		$r - n$	$\cos \delta$		$(r - n) \cos \delta$	$\frac{1}{2}(r - n) \cos \delta$		
833		·07	·841		·059	·029		
835		·04	·841		·034	·017		

The value of $(r - n)$ cos δ was found for each star, the sign being changed for stars north of the zenith, was weighted according to the number of observations on each and the most probable value obtained from them.

My personal error obtained from 118 $(r - n)$ observations on 48 stars is $\cdot 0013_s$, wt. 118, and that of R. M. Stewart who had 138 $(r - n)$ observations on 70 stars is $\cdot 0260^s$, wt. 138. In my case the value is so small, and quite within the range of accidental errors, that my error of bisection may be taken as zero. In Mr. Stewart's case, however, we see that he has an error of bisection and that he sets his wires behind the star when the transit is north of the zenith and in advance of the star when the transit is to the south.

The results were examined to see if the error in any way depended on the declination of the star. To do this the stars were arranged in groups for every 5 degrees of declination and weighted according to the number of observations in each.

The following tables will show these values.

D. B. Nugent			R. M. Stewart		
Declination	Error	Weight	Declination	Error	Weight
°	s		°	s	
10 to 15	·006	12	10 to 15	·016	8
15 – 20	–·008	7	15 – 20	·027	5
20 – 25	·003	13	20 – 25	·035	9
25 – 30	·002	4	25 – 30	·021	6
30 – 35	·008	20	30 – 35	·043	10
35 – 40	·010	21	35 – 40	·022	30
40 – 45	·011	12	40 – 45	·025	14
50 – 55	–·003	6	45 – 50	·031	11
55 – 60	·002	9	50 – 55	·030	5
70 – 75	·001	14	55 – 60	·010	8
	·0016	118	70 – 75	·028	24
			75 – 80	·027	8
				·0262	138

In neither case do we see any systematic change depending on the difference in declination. The difference between the error of any group and the mean error is so small that I think we may take it to be within the limits of accidental errors.

The stars were next grouped according to their magnitudes, the difference between the smallest and the greatest of any group

being 0·5 of a magnitude. No relation between the error and the magnitude of the star was established.

D. B. Nugent			R. M. Stewart		
Magnitude	Error	Weight	Magnitude	Error	Weight
	s			s	
2 to 2·5	−·005	9	1	·019	1
3 − 3·5	−·016	5	2 to 2·5	·021	11
3·5 − 4	·006	18	3 − 3·5	·015	8
4 − 4·5	·011	15	3·5 − 4	·028	13
4·5 − 5	·014	20	4 − 4·5	·030	17
5 − 5·5	−·005	16	4·5 − 5	·023	20
5·5 − 6	−·014	16	5 − 5·5	·026	27
6 − 6·5	·004	14	5·5 − 6	·029	23
6·5 − 7	·012	1	6 − 6·5	·028	17
7·2	−·014	4	7·2	·009	1
	−·0007	118		·0227	138

For stars over 80° declination, whose motion is slow compared with one at the equator, the method of observation was changed, a reversed and a normal observation being obtained of the same transit instead of taking the whole transit normally one night and reversed the next as was the case with those we have considered.

In following the star across the field of the instrument twenty settings are recorded, which are arranged in four groups of five settings, two groups being placed symmetrically on each side of the line of collimation. With this arrangement the first and the last group may be observed with the eye-piece normal and the second and the third with it reversed, or *vice versa*, thus giving the time of transit obtained with the star moving in opposite directions. The difference between a normal and a reversed observation, changing the sign for stars at lower culmination, was taken as twice the error of bisection and for comparison these were reduced to the equatorial interval.

My error, determined from 100 observations on 16 stars, is ·0025^s, which may be considered as zero; and that of Mr. Stewart, determined from 146 observations on 19 stars, ·0162^s, a value slightly smaller than in the case of stars from 10° to 80° declination.

As in the former case the results were examined to see if

there were any changes depending on the declination or the magnitude. The error was also determined separately for the stars observed at upper culmination and for those observed at lower. The changes were so small in all four cases for both observers that they were probably due to accidental errors. The following table will show these values for the two observers : —

D. B. Nugent			R. M. Stewart		
Declination	Error	Weight	Declination	Error	Weight
° °	s		° °	s	
80 to 85	·0013	59	80 to 85	·0178	71
85 – 90	·0041	41	85 – 90	·0146	75
Magnitudes			Magnitudes		
4 to 4·5	·0018	24	2 to 2·5	·0274	8
5 – 5·5	·0007	38	4 – 4·5	·0163	16
5·5 – 6	·0034	13	4·5 – 5	·0154	20
6 – 6·5	·0042	13	5 – 5·5	·0211	40
7 7·5	·0062	12	5·5 – 6	·0153	29
			6 – 6·5	·0110	11
			6·5 – 7	·0143	9
			7 – 7·5	·0147	13
Stars at Upper Culmination	·0020	62	Stars at Upper Culmination	·0177	67
Stars at Lower Culmination	·0032	38	Stars at Lower Culmination	·0148	79

The results obtained from the whole investigation may be summarized as follows :—

(*a*) that D. B. Nugent has no personal error of bisection.

(*b*) that R. M. Stewart has an error, always setting the wires to the left of the star image.

(*c*) that in neither case does the error depend upon the magnitude of the star observed or whether it is observed at upper or at lower culmination.

(*d*) that for R. M. Stewart there is a small difference between the value obtained from stars under 80° and that from stars over 80° in declination, but there does not appear to have been any systematic change in either group depending on the declination.

NOTES FROM THE METEOROLOGICAL SERVICE

Summary Report of the Weather in Canada

June

Temperature.— The mean temperature was above average in all districts between the Rocky Mountains and Lake Superior, also over the greater part of Quebec and the entire Maritime Provinces. In Western Ontario the average was exceeded in a few localities while in others small negative departures were recorded. In Eastern Ontario negative departures ranged between 1 and 4 degrees.

In British Columbia the mean temperature ranged from 5 degrees below average in northern districts to average in the vicinity of Victoria, while in some localities in the southeastern part of the province the average was slightly exceeded. The greatest positive departures were recorded in the Western Provinces and ranged between 3 and 5 degrees.

Precipitation.— In the Western Provinces, Quebec and the greater part of the Maritime Provinces the rainfall, while slightly less than average in some localities, was amply sufficient to promote rapid growth of all grains and vegetables. In parts of the Lake Superior region about twice the usual rainfall was recorded. In Ontario rain occurred quite frequently during the early part of the month, but a severe drought beginning about the 15th continued practically unbroken to the end of the month, over the greater part of Western Ontario. The amount of rainfall was considerably less than average in Western Nova Scotia also and in parts of Southern British Columbia.

JULY

Temperature.— The mean temperature for July exceeded the normal in Southern British Columbia and from the eastern part of the Lake Superior District to the Maritime Provinces, while in other parts of Canada the average value was not reached. The cool weather in the Western Provinces resulted in a mean from 2° to 5° lower than usual, while the excessive heat during the first part of the month in Eastern Canada gave a mean of from 2° to 5° in excess of the normal. Maximum temperatures in Ontario were generally higher than any previously recorded.

Precipitation.— The amount of precipitation was less than the average for July over the greater part of British Columbia, a large area in the central part of Saskatchewan, and in Manitoba excepting a few localities in the vicinity of Winnipeg and Brandon. Over the greater part of Alberta and Saskatchewan, however, the average was exceeded, and even in the districts where less than the normal was recorded, the rainfall with the exception of a very small area in Southern Manitoba, was sufficient to promote rapid growth of all grains. Over the larger part of Ontario and Quebec the amount was less than average. The only districts showing a positive departure from normal were the Central Highlands of Ontario, counties contiguous to Lake Erie and the western end of Lake Ontario, and a comparatively small area in the Lower St. Lawrence Valley. In the eastern districts of New Brunswick and in Cape Breton Island the average was exceeded, while in the vicinity of St. John and over the greater part of Nova Scotia the rainfall was considerably less than the normal amount.

Temperatures for June and July, 1911

Station	June		July	
	Highest	Lowest	Highest	Lowest
Yukon				
Dawson	82	31	83	38
British Columbia				
Atlin	70	32	72	34
Agassiz	83	35	94	42
Barkerville	70	26	78	36
Kamloops	90	40	100	48
New Westminster	79	40	90	46
Prince Rupert	66	40	82	32
Vancouver	72	42	90	48
Victoria	70	40	90	45
Western Provinces				
Battleford	82	38	84	32
Broadview	97	31	92	34
Calgary	82	36	88	33
Carman	91	37	86	43
Edmonton	82	34	86	40
Medicine Hat	93	41	94	42
Minnedosa	90	33	89	37
Moose Jaw	91	39	86	38
Oakbank	86	41	83	42
Portage la Prairie	88	39	87	44
Prince Albert	82	38	84	36
Qu'Appelle	88	38	78	34
Regina	90	36	80	38
Swift Current	96	42	86	38
Winnipeg	89	42	86	43
Ontario				
Agincourt	90	42	103	46
Aurora	87	41	100	42
Bancroft	84	36	100	40
Barrie				
Beatrice	85	40	95	40
Birnam	91	40	99	45
Bloomfield	83	45	93	48
Brantford	92	41	102	46
Bruce Mines	86	40	97	44
Chatham	97	47	103	45
Clinton	87	42	99	45
Cottam	95	41	100	44
East Toronto	94	44	105	45
Gravenhurst	84	39	99	40
Guelph	88	43	99	44
Haliburton	87	37	100	40
Hamilton	95	47	102	51
Huntsville	83	39	95	46
Kenora	90	40	89	48
Kinmount	84	34	98	41
Kingston	75	47	85	50
Lakefield	80	49	100	50
London	93	42	102	45
Lucknow	85	35	97	43
Madoc	84	42	99	45
Meaford				
Midland	85	50	101	60
North Gower				
Otonabee				
Ottawa	85	41	95	50
Owen Sound	90	40	104	45
Paris	91	39	102	40
Parry Sound	90	44	98	47
Peterboro'	86	45	100	44
Point Clark				
Port Arthur	80	40	94	42
Port Burwell	82	42	89	47
Port Dover	86	45	91	48
Port Hope				
Port Stanley	83	44	88	48
Ronville	83	40	96	45
Sarnia				
Southampton	84	41	91	46
Stonecliffe	80	37	109	45
Stony Creek	93	44	103	47
Stratford				
Toronto	92	47	103	48
Uxbridge	87	42	98	44
Wallaceburg	93	44	99	48
Welland	86	48	100	48
White River	82	34	90	36
Quebec				
Brome	81	38	93	44
Father Point	78	37	78	46
Montreal	83	50	95	56
Quebec	85	41	93	52
Sherbrooke	83	40	96	47
Maritime Provinces				
Charlottetown	80	36	88	54
Chatham	83	37	95	53
Dalhousie	82	35	85	50
Fredericton	85	38	95	49
Halifax	84	37	91	50
Moncton	82	35	95	48
St. John	81	44	82	53
St. Stephen	86	35		
Sussex	82	36	92	48
Sydney	80	38	92	47
Yarmouth	80	39	86	48

Earthquake Records by the Milne Seismograph

TORONTO

R. F. Stupart, Director.

P.T. = Preliminary Tremors. L.W. = Large Waves. Time is Greenwich Civil Mean Time, 0 or 24 h = midnight.

No.	Date 1911		P.T. Comm.	L.W. Comm.	Max.	End.	Max. Amp.	Durat.	Remarks
			h m	h m	h m	h m	mm.	h m	
1012	June	7	V_1 11 9·1 V_2 11 10·3	B 11 15·2 B 11 19·6	11 23·8	14 41·4	20+	3 32·3	Mexican Earthquake
1013	"	15	5 44·7			5 47·1	0·02	0 2·4	
1014	"	15	14 38·5 14 43·8	14 46·9 14 50·3 B 14 55·3	15 8·2	17 32·7	2·3	2 54·2	Moderate P.Ts. Marred by local cause.
1015	"	21	13 6·8			13 9·8	0·05	0 3·0	Doubtful as to being seismic
1016	"	25	16 11·3			16 14·2		0 2·9	
1017	"	26	12 3·4			12 6·6	0·1	0 3·2	
1018	"	30	11 56·9			11 58·5	0·05	0 1·6	
1019	"	30	23 50·0			23 51·4	0·05	0 1·4	
1020	July	1	22 17·1	V_2 22 20·0 LW 22 22·1	22 22·5	23 17.6	3·0	1 0·5	California
1021	"	4	13 57·3	13 58·5	14 13·4	15 8·1	0·4	1 10·8	Inc. vib. at 14h 3m
1022	"	11	22 44·1			22 45·5	0·05	0 1·4	Doubtful as to being seismic.
1023	"	11	22 48·6			22 51·4	0·05	0 2·8	
1024	"	12	4 28·8	4 38·8	4 42·2	6 57·9	0·3	2 29·1	Continuous.
1025	"	13	21 51·8	21 53·8	12 54·2	12 54·8	0·05	0 3·0	Doubtful as to being seismic.
1026	"	19	10 26·0	10 30·1	10 31·6	11 7·6	0·2	0 41·6	

Period 14·8 seconds. 1 mm. = 0″·64.

VICTORIA, B. C.

E. B. Reed, Superintendent.

No.	Date 1911		P.T. Comm.	L.W. Comm.	Max.	End	Max. Amp.	Durat.	Remarks
			h m	h m	h m	h m h m	mm.	h m	
1035	June	7	V_1 11 9·6 V_2 11 11·1	B 11 16·2 B 11 19·1	11 28·8	14 28·5	over 25	3 18·9	Mexican Earthquake.
1036	"	15	5 44·4		5 47·7	5 52·8	0·2	0 8·4	
1037	"	15	V_1 14 37·9 V_2 14 41·3	14 48·0	14 49·4	17 29·9	3·9	2 52·0	Moderate
1038	"	19	15 18·4		15 19·4	15 22·4	0·15	0 4·0	
1039	July	1	22 5·2	22 6·3	22 8·2	23 10·6	3·0	1 5·4	California
1040	"	4	13 58·22	14 0·9	16 5·4	14 49·0	0·2	0 50·8	P.Ts. marred by local cause.
1041	"	12	4 20·8	4 31·6	4 33·8	6 37·7	1·1	2 16·9	Small and prolonged
1042	"	19	10 23·6	10 24·5	10 25·2	10 36·2	0·2	0 12·6	

Period 15 seconds. 1 mm. = 0″·76

J. Y.

MAGNETIC OBSERVATIONS

There were no disturbances of importance during the months of June and July, the greatest daily amplitudes being as follows:

Declination – June 4, 0° 40′·0 July 1, 0° 37′·8
Bifilar – June 9, ·001866 July 1, ·001467

Declination

Month	Mean of Month	Max.	Date	Min.	Date	Monthly Range	Amplitudes—Mean Daily	
							From hourly readings	From Means of Extremes
1911	° ′	° ′		° ′		° ′	° ′	° ′
June	6 8·1	6 26·1	4	5 45·3	4	0 40·8	0 11·6	0 17·7
July	6 8·5	6 24·8	2	5 41·9	18	0 42·9	0 11·9	0 18·6

Bifilar

	C.G.S. units							
June	·16214	·16320	9	·16096	10	·00224	·00036	·00067
July	·16217	·16311	17	·16125	1	·00186	·00047	·00068

Inclination

Month	Mean
	° ′
June	74 38·8
July	74 39·0

ASTRONOMICAL NOTES

BRIGHTNESS OF THE NIGHT SKY.— Summary of observations made on Mount Whitney by C. G. Abbot. Visual photometric observations on the brightness of the sky by night were made with the Kapteyn-Yntema apparatus by the writer on Mount Whitney, at 4420 meters elevation, on September 7, 1909, and August 6 and 7, 1910. The mean brightness in the galaxy was found 2·1 times that of the polar sky. The brightness of the sky within 10° of the horizon was found 1·4 times that of the polar sky. Not altogether satisfactory observations indicated that a square degree of polar sky gives 0·0746 as much light as a first magnitude star in the zenith, if both are observed at Mount Whitney. Compared with a first magnitude zenith star at Washington, a square degree of polar sky seen from Mount Whitney would be 0·093 as bright.— *Astronomical Journal*, No. 627, (June).

NUTATION.— In order to understand Newton's Nutation we must revert to the motion usually called Precession and look into it in rather more detail than is usual in the elementary handbooks. It is well known that the axis of the earth is oblique, and that both the sun and the moon by their pull on the protuberant part of the equator are tending to abolish the tilt and reduce the equator to the ecliptic. And they would have done so centuries ago but for the fact that the earth is spinning, and, in consequence of a well known law of spinning bodies, the axis, instead of dipping, sways round, and this swaying motion is called Precession. It is usually illustrated by hanging a small weight on to a gyroscope or by a top spinning on the table with its axis slightly out of the vertical. All this leaves the impression that Precession is a uniform and steady motion, and that idea

is only enhanced when one hears of the constant of Precession being 50″ per annum, and one knows that to correct a star's place one must add a fraction of its Annual Precession according to the number of days elapsed from January 1.

Thus it would at first appear that the motion of the Earth's axis is uniform and steady, and also that the axis maintains a constant inclination to the ecliptic. Neither of these facts is correct, and Newton recognised this, giving the name Nutation to the minute fluctuations of inclination, or, as it is more usually called, to the Obliquity of the Ecliptic, and thus the word Nutation makes its first appearance in astronomy.

There is, in fact, a close relationship between the problems of Tides and Precession, and we shall see that just as the Tides rise and fall *twice* in a day so Precession fluctuates *twice* in a year. —J. A. Hardcastle, *Journal British Astronomical Association*, No. 8.

Theory of Grazing Collisions.—*Journal B.A.A.*, No. 8, Rev. M. Davidson contributes a paper dealing with the suggestions of Mr. Bickerton re-grazing collisions as origins of temporary stars. The investigations of Mr. Bickerton on the partial grazing impact of two suns seem to leave out of consideration one important fact: that is the disruption produced by the bodies upon each other due to differential attraction.

Summary.—Two gaseous bodies approaching each other will have tidal distortions produced by their mutual differential attraction even at a considerable distance apart.

Probably before they come within the Roche sphere, but *certainly* when they are within it, disruption will take place on a considerable scale. This disruption is largely due to the expansive force of compressed gases which have been relieved of their pressure.

The result of this disruption may be spiral nebulæ, the remains of each of the suns pursuing a parabolic path around their common centre of gravity.

If the bodies be in a condition similar to our earth, that is, with a considerable internal temperature, the same results will occur, but on a smaller scale.

When the bodies are in a cold condition, fragmentation will occur within the Roche sphere, but, as there are no internal forces acting, there will not be such considerable eruptions as in the former cases. Should the bodies be originally pursuing paths which would ultimately cause a graze, it is probable that no such graze will occur, since a considerable quantity of each body will be previously reduced to the condition of dust.

JUPITER.— The Red Spot region and the S. tropical disturbance still claim the chief attention of Jovian observers, but there are other features of great interest as well, including some brilliant spots on the rift that runs longitudinally through the S. equatorial belt. The Red Spot itself can now be distinctly seen with large apertures as a complete oval, and it is desirable that its transits, or those of the hollow over the central meridian, should be carefully noted, as there is some evidence of recent minor fluctuations in its motion. During the year ending May last its mean motion appears to have been more rapid than at any time since 1881.— T. E. R. PHILLIPS. *Journal B. A. A.*, No. 8.

BROOKS' COMET.—HARVARD COLLEGE BULLETIN No. 460, gives a corrected ephemeris for Brooks' comet as follows:—

MIDNIGHT.	RIGHT ASCENSION.			DECLINATION.		
	h	m	s	°	′	″
1911, Sept. 5	18	54	15	+ (North) 55	48·2	
" 9	18	4	6	57	9·6	
" 13	17	10	38	57	9·4	
" 17	16	18	6	55	42	44
" 21	15	31	15	53	0	39
" 25	14	51	17	49	21	7
" 29	14	17	44	44	58	56
Oct. 3	13	49	52	40	6	42
" 7	13	26	46	34	51	0

It will be 14,000,000 miles nearer the earth on Oct. 7 than it is now. Perihelion passage, Nov. 11, 1911. On August 23, the comet was near α Cygni.

ROTATION OF VENUS.—In 1900 M. Belopolsky had found the length of this rotation (of Venus on her axis) is short, a little more than one day. This conclusion being in contradiction with that which Mr. Slipher had arrived at in 1903, the question remained in suspense. M. Belopolsky has continued his researches upon the same subject, and his results of 1903, 1908 and 1911 have confirmed those that he had obtained previously. He has, moreover, verified his instrument by means of Mars, the duration of whose rotation is known, and he found for its equatorial velocity 0·354 per second instead of 0·254 km. The value found for Venus, 0·38 km., corresponds to a period of rotation 1·44 days.—*The Observatory*, No. 438, (August).

ASTRONOMY IN MEXICO.—Under the auspices of the Astronomical Society of Mexico. The first of a series of popular lectures on "Astronomy" was given in the City of Mexico, on August 2, by the Society's Secretary, Professor Luis G. León, in the Lecture Hall of the National Preparatory School. The President of the Republic, Hon. Francisco L. de la Barra, who has been a member of the Society for a number of years, occupied the chair.—*Boletin Sociedad Astronomica de Mexico*, No. 114.

J. R. C.

KEPLER

O Thou, whose ancient all-disclosing light
  Brooded upon the dark, primeval deep
  When first the firmament was fixt to keep
The waters from the waters, with new sight
I trace the ample courses of Thy might
  Along the sunlit pathways through the steep
  Abyss of heaven, I see the planets sweep
And hear the music of the spherèd night.

Lo, I have found the wondrous three-fold law
That swings the balanced worlds. I stand in awe
  Of mine own vision, conscious of its worth,
  While motion gives emotion larger birth,
    Nor fret for recognition, I can wait
    As patient as the ages, calm as fate.

TORONTO, July 8, 1911. ALBERT D. WATSON.

NOTES AND QUERIES

Communications are Invited, Especially from Amateurs. The Editor will try to Secure Answers to Queries.

Query

I have an idea that the ether space outside of our air envelope is black as night. Is this an accepted fact? I know that if you look at the sky during the day, from the bottom of a well, you can see stars, which leads me to believe that outside of the atmosphere, which seems to turn the sunlight into light and heat, it is dark. Again, if it is not dark I cannot understand why there is not light on both sides of the earth at night, just as you see light on both sides of a tree a few feet away from a lamp post.—J. W. H.

Answer

The views outlined in this query are essentially in agreement with those held by scientific men generally. The process by which we see a body is believed to be as follows. The ether is a very attenuated medium which fills the depths of space and also penetrates all material bodies whether solids, liquids or gases. Thus the molecules of all bodies are surrounded by the ether.

The molecules of the body are in rapid vibration, the higher the temperature the more rapid the vibration. The vibrating molecules set in motion the surrounding ether; and just as a motion given to the surface of water spreads out in every direction by means of waves, so this motion in the ether spreads out in all directions. As it passes through the ether it is a wave-motion, but the waves themselves cannot be seen. When, however, they reach the retina of the eye they set its particles in vibration and we say we have the sensation of light. If the waves fall upon matter, (*i. e.* what we ordinarily call matter), its molecules are put in vibration, these again start out new waves in the ether, and when these reach the eye we have the sensation of light and say that we *see* the body from which they have come.

Far out in space there is no matter and hence there is

nothing to be excited and to send to us light. Thus the space would appear absolutely black if the eye were screened from the sun and other bright bodies.

Ether waves can produce other effects besides the sensation of light. They carry energy which is able to produce the effects we observe in heating, in some chemical processes (photography, for instance), in wireless telegraphy and probably in other forms of which we know little. C. A. C.

Query

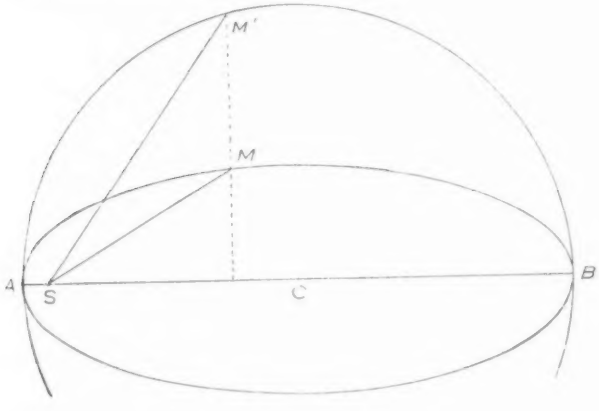
How can the distance of Halley's Comet from the sun and its velocity in its orbit be determined at any time, say two years after passing perihelion, April 19, 1912?

Answer

Questions similar to the above are continually being asked, and the following answer is given in *Knowledge* for June (page 225).

The following method can be used when the perturbations of the planets are not taken into consideration.

Let the figure represent the path of the comet in its orbit, where *A B* is the axis major of the ellipse described, *S* the sun in one of the foci of the ellipse, *C* the centre, and *M* the comet two years after passing perihelion. Of course *A* will represent the perihelion point.



We assume the following data in connection with Halley's Comet :

Periodic time	76·37 years.
Perihelion distance	·5889 astronomical units
Eccentricity	·967
Aphelion distance	35·411 astronomical units.

The angle $A\,S\,M$ described by the radius vector is called the "true anomaly," and is generally denoted by v; the angle described by the radius vector, on the assumption that it moves uniformly, is called the "mean anomaly;" it is usual to denote it by M. Now, if we suppose a circle circumscribed about the ellipse, and we draw through the point M an ordinate meeting this circle in M', the angle $A\,S\,M'$ is called the "eccentric anomaly" and is denoted by u.

From the properties of an ellipse the equation

$$M = u - e \sin u$$

is easily deduced, where e is the eccentricity.

Now $M = \dfrac{360^\circ}{76{\cdot}37} \times 2 = 9^\circ\ 25'\ 40''$.

Therefore, $9^\circ\ 25'\ 40'' = u - {\cdot}967 \times 57^\circ{\cdot}3 \sin u$.

The factor $57^\circ{\cdot}3$ is introduced since this is the number of degrees in a radian.

This equation can be solved approximately by a graphic method; the one used is the well-known method by drawing a curve of lines. As a first approximation u comes out about 55°.

To find its exact value let u be actually $55^\circ + \theta^\circ$ where θ is small.

Hence $9^\circ\ 25'\ 40'' = 55^\circ + \theta^\circ - {\cdot}967 \times 57{\cdot}3 \sin (55^\circ + \theta^\circ)$.

Now $\sin (55^\circ + \theta^\circ) = \sin 55^\circ \cos \theta^\circ + \cos 55^\circ \sin \theta$,

$$= \sin 55^\circ + \frac{\theta}{57{\cdot}3} \cos 55^\circ,$$

since $\cos \theta = 1$ (nearly) and $\sin \theta^\circ = \dfrac{\theta}{57{\cdot}3}$

as θ is very small.

We therefore obtain

$$45^\circ\ 34'\ 20'' = \cdot967 \times 57\cdot3 \left(\cdot81915 + \frac{\cdot57358}{57\cdot3}\ \theta^\circ \right);$$

$$\text{or } \theta^\circ + 45\cdot57222 = 45\cdot387 + \cdot55467\ \theta^\circ,$$

$$\cdot44533\ \theta^\circ = -\cdot185,$$

$$\text{and } \theta^\circ = -\cdot4157^\circ = -24'\ 26''.$$

Hence value of u is $55^\circ - 24'\ 26''$

$$= 54^\circ\ 35'\ 34''.$$

The true anomaly is given by the formula

$$\tan \tfrac{1}{2} v = \sqrt{\frac{1+e}{1-e}}\ \tan \tfrac{1}{2} u,$$

$$= 7\cdot72 \tan 27^\circ\ 17'\ 47'',$$

$$= 7\cdot72 \times \cdot51606$$

$$= 3\cdot9814.$$

Hence $\frac{1}{2} v = 75^\circ\ 54'$

or $v = 151^\circ\ 48'$ approximately.

If r is the distance of the comet from the sun, the value of r is given by the formula

$$r = a\ (1 - e \cos u),$$

where a is the semi-axis major, or 18 astronomical units.

Hence $r = 18\ (1 - \cdot967 \cos 54^\circ\ 35'\ 34'')$,

$$= 18\ (1 - \cdot56028),$$

$$= 7\cdot91496.$$

Its distance from the sun would, therefore, be about eight times the distance from the sun to the earth. It would be, at this time, between the orbits of Jupiter and Saturn.

The formula to determine the velocity at any point in the orbit distant r from the sun is

$$V^2 = \frac{2\mu}{r} - \frac{\mu}{a}$$

where μ is a constant and a is the semi-axis major.

Substituting 7·91 for r and 18 for a we find

$$V^2 = \cdot1979\ \mu,$$

$$\text{or } V = \cdot445 \sqrt{\mu}.$$

The contrast μ can be found from a consideration of the motion of the earth in its orbit. Since the comet describes an

ellipse around the sun, μ will be the same for the earth and the comet. Using the equation

$$v^2 = \frac{2\mu}{r} - \frac{\mu}{a}$$

for the earth, and remembering that $r = a$ very nearly, since the eccentricity of the earth's orbit is only $\frac{1}{60}$, we have

$$v^2 = \frac{2\mu}{a} - \frac{\mu}{a} = \frac{\mu}{a}.$$

Now the velocity of the earth about the sun is about 18¼ miles per second, and $a = 1$ astronomical unit; therefore, $\mu = (18{\cdot}25)^2$ or $\sqrt{\mu} = 18{\cdot}25$.

Substituting in the expression $l' = {\cdot}445\sqrt{\mu}$, we have

$$l' = {\cdot}445 \times 18{\cdot}25$$
$$= 8{\cdot}12 \text{ miles per second.}$$

The perturbation produced by the planets will slightly alter some of the elements, but the above results may be taken as approximately correct.

The Astronomical and Astrophysical Society of America

This Society held its twelfth meeting at the Dominion Astronomical Observatory, Ottawa, on August 23, 24, 25. This was the first meeting held in Canada and it was a success, the attendance comparing favorably with that at previous meetings. An account of the meeting will be given in the next issue of the Journal.

C. A. C.